Intra-Oral Scanning: State of the Art in Dentistry?

Dr Daniel TS FANG

BDS(U. London), MDS(HK), AdvDipProsthodont(HK), MRD RCS(Ed), MRACDS(Pros), MGDS RCS(Ed), MFGDP(UK), FRACDS, FICD, FCDSHK (Pros), FHKAM (Dental Surgery)

Hon. Clinical Associate Professor, Faculty of Dentistry, University of Hong Kong
Specialist in Prosthodontics, Private Practice

Dr Daniel TS FANG

This article has been selected by the Editorial Board of the Hong Kong Medical Diary for participants in the CME programme of the Medical Council of Hong Kong (MCHK) to complete the following self-assessment questions in order to be awarded 1 CME credit under the programme upon returning the completed answer sheet to the Federation Secretariat on or before 30 June 2016.

Introduction

We live in a digital world. Technological changes have been making an impact in various aspects of our daily lives (van der Zande et al., 2013). These changes have also gained ground in the development of dentistry (Bauer, 2001; Eaton, 2008). Clinic records and file keeping in practice management, photography and radiology in diagnosis, navigation implant surgery and CAD-CAM restorations in treatment provision, digitalisation has gained popularity.

One such digital innovation has made significant inroads to daily dental practice ---- intra-oral scanning. Francois Duret introduced the first intra-oral digital scanner for restorative dentistry (Duret et al., 1971). The past 30 years have seen rapid advancement of the digital intraoral impression technique (Ender et al., 2003; Reich, 2007; Christensen, 2008; Beuer, 2008; Birnbaum, 2008; Christensen, 2009)

There are 4Ps to the intra-oral scanning technology:
Potential: What does it do?
Process: How does it work?
Probabilities: How accurate is it?
Problems: What are the challenges?

Potential: What does it do?

Analog impression procedures use an elastomeric impression material to generate an imprint of the oral situation. With the imprint, a stone cast is poured. Then an intracoronal (post-core, inlay, onlay) or extracoronal restoration (crown, bridge) is fabricated.

Intra-oral scanning technology uses a 3-dimensional camera to capture the data from the area of the tooth preparation, adjacent and opposing structures, and then convert them to virtual impressions in a digital format (Patzelt et al., 2014; Yuzbasioglu et al., 2014; Zandparsa, 2014; Sannino et al., 2015). The restoration can then be fabricated using computer-aided design software and computer numerical control milling machines (Ng et al., 2014; Pradies et al., 2015). Contrary to the conventional analog methods, a physical stone cast is not needed, but can be produced using 3D rapid prototyping technology (Bosch et al., 2014).

There are numerous potential benefits in incorporating intra-oral scanning in daily dental practice.

1. Better dentistry

Less remake

The use of magnification in operative dentistry has been proven to improve the accuracy and quality of work produced. Dental loupes magnify the object by two to three times, but with the reduction of field of view. Once the image is captured by the intra-oral scanner, the object can be evaluated in real time without any limitation in magnification.
Literally, you get what you see. (Fig. 1)
Errors in the tooth preparation (presence of undercut, inadequate clearance) can be identified and rectified at chairside, reducing the need for remake of the restoration.

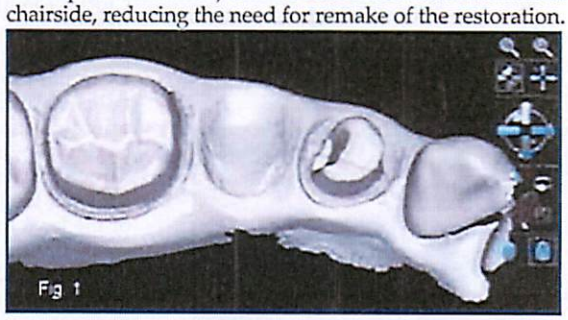
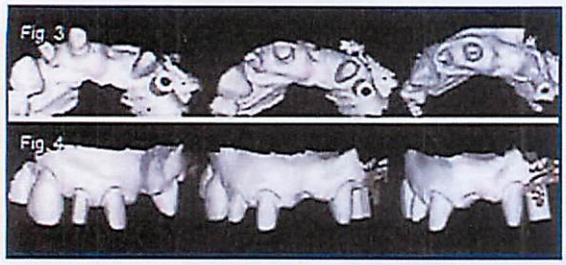


Fig. 1

Improved quality

For construction of a dental bridge, aligning the path of insertion of various abutments can be challenging. Once the prepared abutment teeth are scanned, the images can be viewed from different angles, and software available to ensure a single path of insertion (Fig. 2). Any undercut is also highlighted to assist in the modification in order to produce high quality dentistry (Figs. 3, 4).

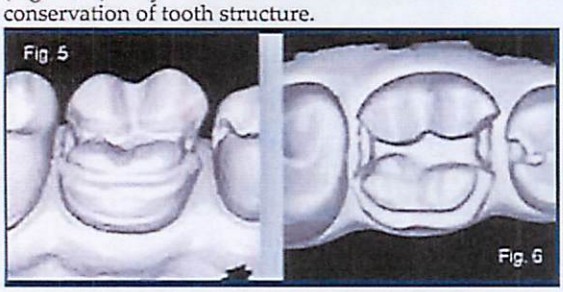
Fig. 2



2. Better patient care

Less discomfort
Silicone materials like Imprint (3M ESPE), Aquasil (Dentsply), polyether materials like Impregum F or Monophase S (3M ESPE) are not the best tasting impression material available, although they are very accurate. Typically, the handling time is 2'30" outside the mouth and 3'30" in the patient's mouth, not to mention the re-takes when there are unavoidable air voids or tears in the impression. What if our patients do not need to go through such an ordeal for the sake of recording an impression? Now, we can do this digitally. Studies showed significant differences in time consumption and patient preference in favour of the digital technique (Lee and Gallucci, 2013; Wismeijer et al., 2014; Schepke et al., 2015)

More tooth conservative
In tooth preparations, there is always a delicate balance between destruction of healthy tooth structure and the risk of undercut affecting the fit of the final restoration. Once scanned, the image of the preparation can be evaluated in real time to assess the degree of taper (Figs. 5, 6). Any corrections can be made with maximal conservation of tooth structure.



3. Streamline practice management

Model storage
According to the local regulations, a dentist has the duty to keep patients' records for a period of seven years. In a place like Hong Kong where office space is a premium, the idea of storing patients' study casts and working models without occupying any physical space would be very welcoming. We can scan and store them digitally.

Communication with technician
The intra-oral scanner is an excellent tool for communication with the dental technician. Scanned images of the tooth preparation can be shared, so that the design of the restoration with regard to placement of the finish margin, position of the contact points, profile of the restoration can be discussed with clarity (Fig. 7).

Process: How does it work?

Currently there are two types of intra-oral scanners: single image camera and video camera.

Single image camera records individual images of the tooth preparation, adjacent and opposing teeth. Common systems available in Hong Kong are: CEREC Bluecam (Sirona), iTero (Align Technology), Trios (3Shape), CS 3500 (Carestream Dental). The camera records around three teeth in a single image. For the full arch, a series of overlapping images are taken, and the software would stitch these images to form a 3D virtual model. The camera is required to be positioned at different angles to record the variations in height of the object. Those areas not captured by the overlapping images would be extrapolated by the software to augment the missing data in the virtual mode (Alghazzawi, 2016).

Video camera type captures continuous streams of high-resolution video images, usually at 20 frames per second, as the patient is being scanned. The images are then converted by the software to 3D data sets and displayed in real time. Current systems available in Hong Kong are: True Definition Scanner (3M ESPE), CEREC Omnicam (Sirona), Apollo DI (Sirona), PlanScan (Planmeca).

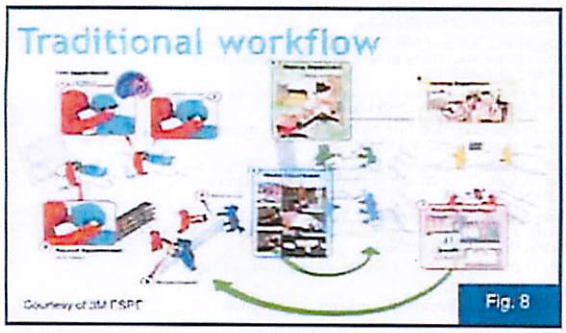
Once the tooth has been prepared clinically to receive either an intracoronal or extracoronal restoration, the operator manoeuvres the image acquisition device (scanner wand) over the preparation in multiple directions according to the manufacturer sequential protocol for image capture. The scanner wand consists of the lens, mirrors and a light source using either LED (blue LED True Definition scanner, blue LED Trios, white LED CS 3500, white light CEREC Omnicam) or laser (blue laser PlanScan, red laser iTero). Some intra-oral scanner systems require light powdering with titanium dioxide over the preparation for improvement in accuracy of data acquisition [True Definition scanner, CEREC Apollo DI] (Zimmermann et al., 2015; Ting-Shu and Jian, 2015; Abdel-Azim et al., 2015).

The opposing dentition is then scanned using the same protocol, and the interocclusal record attained through a buccal scan when the patient is asked to close at centric occlusion (maximal intercuspal position). For implant restorations, a scan body is connected directly over the implant fixture to capture its 3D orientation in relation to the adjacent dentition. A scan body is usually a non-reflective plastic, precision milled from polyether ether ketone [PEEK] (Lin et al., 2013; Rauscher, 2014).

The images are electronically transmitted using an STL file to the laboratory CAD system either in-house or outsource production centre where the final restoration is made. The entire construction can be processed model-free digitally. Alternately, polyurethane working

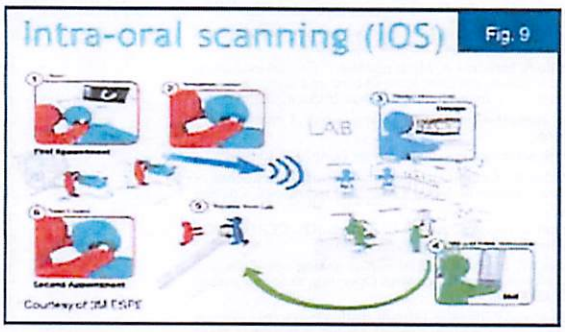
casts are fabricated either by milling or 3D rapid additive manufacturing (Schmitter & Seydler, 2012; Kurbad & Kurbad, 2013; da Cunha et al., 2015)

Probabilities: How accurate is it?



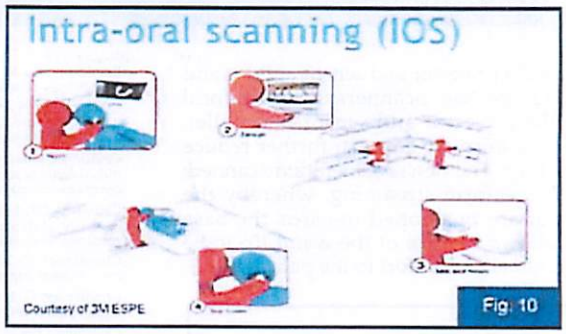
Traditional workflow
From the time of tooth preparation to the delivery of an intracoronal or extracoronal restoration, there are a number of stages involved: analog intraoral impression, chairside construction of provisional restoration, pouring and sectioning of dental cast, wax-up and casting of metal framework, repeated firing of ceramic over framework, delivery of glazed restoration to the dental office (Fig. 8). Not only the whole process is time-consuming, any error introduced in any of the stages would potentially lead to misfit of the final restoration.

With the use of the intra-oral scanner, the procedure of construction is simplified. The intracoronal or extracoronal restoration can be manufactured at an outsource facility or in-house.



Intra-oral scanning with lab fabrication
After tooth preparation, the impression is captured digitally with the intra-oral scanner. The information is then sent to the laboratory in STL format, where the restoration is designed and milled (Fig. 9). There are less steps involved, less chance for error to be introduced.

Intra-oral scanning with in-office fabrication
Instead of sending the STL file of the scanned image to an outsource facility, the restoration is designed and milled within the dental office (Fig. 10). Same day delivery of the final restoration is possible.



The accuracy of an impression is exceptionally critical for construction of well-fitting restorations (Wostmann et al., 2009). There are two factors that affect accuracy: trueness and precision. Trueness describes the deviation of the impression geometry from the original, while precision describes the deviation between repeated impressions (Chandran et al., 2010; Ender & Mehl, 2014).

Several studies have evaluated the trueness and precision of intraoral impressions, focusing on single or short span bridge preparations. Digital impressions are highly accurate, comparable and some researchers showed even better than conventional analog impression methods (Ceyhan et al., 2003; Rudolph et al., 2007; Beuer et al., 2008; Chandran et al., 2010; Hoyos et al., 2011; Akyalcin et al., 2013; Anadioti et al., 2014; Vennerstrom et al., 2014; Ahrberg et al., 2015).

Boeddinghaus evaluated the in vivo trueness of three digital impression systems: CEREC Omnicam (Sirona Dental Systems), True Definition Scanner (3M ESPE), 3Shape Trios (3Shape), as compared with control using conventional elastomeric impression and model digitised with an extra-oral contact scanner 3Shape D700 (3Shape). In 24 patients, 49 teeth were prepared and Zirconia copings milled. The mean marginal gaps of the copings were evaluated: control 113µm (81 - 157µm), 3M LAVA True Definition 88µm (68 - 136µm), 3Shape TRIOS 112µm (94 - 149µm), CEREC Omnicam 149µm (114 - 218µm). The authors concluded that digital intraoral impressions could be considered as an alternative to conventional impression consecutive to digital workflow (Boeddinghaus et al., 2015).

For full arch impressions, Ender compared in vivo precision of conventional and digital impressions, and found that the precision across the complete arch scans did not differ significantly among the seven digital impression systems studied. All of the digital systems, however, showed a larger standard deviation compared with the high precision conventional impression materials (Ender et al., 2016).

Problems: What are the challenges?

Patient factor -- Comfort
As the mandible opens in an arc, scanning at the posterior aspect of the jaw may pose certain degree of discomfort to the patient. Many systems attempt to address this with a tapering design of the scanner wand tip (Fig. 11). The size of the wand tip is related to the method of image acquisition. Scanners using laser

triangulation require the projector and sensor at the wand tip, accounts for its large size. Scanners using confocal photometry have the projector and sensor in parallel, and utilizes a series of mirrors. This can further reduce the size of the wand tip. The newer generation scanners adopt continuous waveform streaming, whereby the projector and sensor are positioned towards the base of the wand. This allows the size of the wand tip to be constructed with minimal discomfort to the patient.

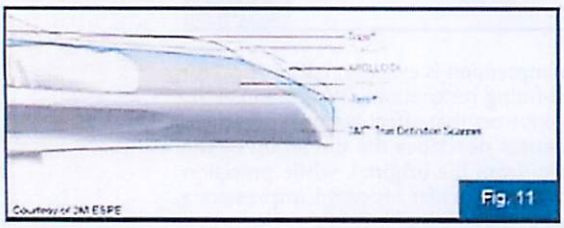


Fig. 11

Dentist factor -- Barriers to change

A study on barriers to adoption in dentistry indicated costs, lack of comfort with technology and legislation issues to be the main obstacles (Flores-Mir et al., 2006). van der Zande found that fear of lack of sustained benefits, dentist's age, the number of working years left and lack of skills in using digital applications were the main barriers to adoption (van der Zande et al., 2013).

Equipment factor -- Line of sight

The intra-oral optical scanner can only record images visible to the camera. When the tooth preparation is partially obscured by soft tissue, saliva or blood, the images would not be captured accurately (Logozzo et al., 2014). Future development in ultrasonic impressions may be able to address this drawback. Ultrasonic waves have the potential to penetrate the gingiva non-invasively without the use of retraction cord, and are unaffected by moisture over the tooth preparation (Vollborn et al., 2014; Chuembou et al., 2015).

Conclusion

For providing better care to patients, for further improving the quality and scope of restorative work, for streamlining practice management, it is prudent for the aspiring dentist to explore more about this innovation, and hopefully in due course embrace this technology. Intraoral scanning is the future of dentistry, and the future is here today.

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Evidence-based Orthodontics

Dr Albert MP LEE
BDS, MSc, FRACDS, FCDSHK(Paed Dent)
FHKAM(Dental Surgery)

Editor

Dr Albert MP LEE

In providing dental treatment for patients, dental practitioners are faced with the dilemma of making the best clinical decision for patients with less uncertainties. This is usually based on the dentists' background training, knowledge and experience. However in dealing with uncertainties, the best clinical evidence is based on research in ascending importance including case reports, case series, case control studies, prospective cohort studies, randomised clinical trial studies and systemic review of treatment results.

Uncertainties present in all clinical decisions and are best reduced by research. In contrast, uncertainties will increase by claims based on low evidence. In a recent presentation at the 23rd Convocation of the Royal Australasian College of Dental Surgeons by Professor Kevin O'Brien, Professor of Orthodontics at the University of Manchester, he illustrated examples in orthodontics to discuss areas of dentistry with uncertainties in decision making by clinicians.

One of the best examples is the effect of early orthodontic treatment for Class II malocclusions in young children with large overjets versus delayed treatment in adolescents. Claims for the benefit of early treatment include shorter treatment time, skeletal change, reduction in trauma, no extraction required and to a certain extent to improve breathing in young children.

However clinical research and evidence based on randomised clinical trials illustrate that there are no significant differences in early treatment in young children as compared to delayed treatment in adolescents. The only benefit of early orthodontic treatment for Class II malocclusions in young children with large overjets is to reduce the incidence of incisal trauma. There is a 9% reduction of dental trauma with early treatment as compared to delayed treatment in adolescents. However from the public health point of view, in order to prevent one child from experiencing incisal trauma, ten children need to be treated earlier. Therefore, except for the reason of preventing dental trauma, claims for the benefit of early treatment in dental and skeletal factors are low from the evidence-based data.

Nowadays there are many claims by commercial products for faster orthodontic treatment time and different treatment methods with low evidence-based information on the market. Further researches are required to assist dental practitioners and specialists to make clinical decisions in many aspects of dentistry especially in dealing with treatment outcomes and uncertainties.

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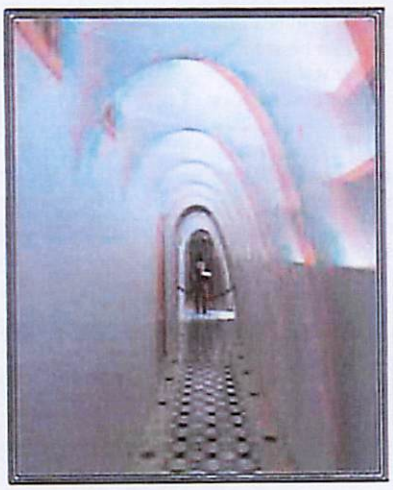

A corridor on the top floor of the famous Casa Batlló in Barcelona, Spain. The perfectly synchronised shot captured depth and the brief emergence of a random tourist added a point of interest to the picture. Canon Powershot S100 rig in portrait orientation.

Dr Siu-fai LEUNG
BDS (HK) MSc (Lond.) FRACDS
Specialist in Endodontics, private practice

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Chairpersons: Dr Ludwig CH TSOI & Dr LI Shu-kin

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  Prof Brian TOMLINSON
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- **Gout and its Comorbidities to the Elderly**
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- **Advance Treatment for T2DM – Role of SGLT2 & GLP1**
  Dr TSANG Man-wo
  (Consultant, Department of Medicine & Geriatrics, United Christian Hospital)

Lunch Symposium – Allergy Prevention
Chairperson: Dr Jane CK CHAN

- **Emerging Trends in Allergy Diagnosis, Treatment & Prevention**
  Prof LEUNG Ting-fan
  (Professor, Department of Paediatrics, Faculty of Medicine, The Chinese University of Hong Kong)

Session III – Paediatric Epilepsy
Chairpersons: Dr LEE Tsz-leung & Mr Frankie PL SIU

- **Tertiary Level Surgical and Dietary Treatment of Paediatric Refractory Epilepsy: Challenges and Opportunities**
  Dr Mario WK CHAK
  (President, The Federation of Medical Societies of Hong Kong)
  Ms Carmen KM YEUNG
  (Dietitian, Hong Kong Children's Hospital)

Session IVa – Allergy and Autistic Spectrum Disorder
Chairpersons: Dr LEE Tak-hong & Dr HUNG Se-long

- **How to Face the Allergy Epidemics? – Highlights of the Guidelines for Allergy Prevention in Hong Kong**
  Dr Alson WM CHAN
  (Specialist in Paediatric Immunology & Infectious Diseases)
- **Holistic Care for Autism Spectrum Disorder : Building Castles in the Air?**
  Dr LAM Siu-man
  (Chief of Service, Department of Child & Adolescent Psychiatry, Castle Peak Hospital)

Session IVb – Geriatrics
Chairpersons: Dr Raymond SK LO & Dr Andrew CHAN

- **Medical Diagnosis and Management of Dementia in Older People**
  Prof Timothy KWOK
  (Professor, Department of Medicine and Therapeutics, Prince of Wales Hospital, The Chinese University of Hong Kong)
- **The Mouth and the Body – How Are They Connected in Older People?**
  Dr Frankie HC SO
  (Specialist in Community Dentistry)

Session Va – HIV Infection and Mental Health
Chairpersons: Dr NG Yin-kwok & Dr Desmond NGUYEN

- **People Living with HIV Infection**
  Dr Thomas MK SO
  (Specialist in Infectious Disease, Private practice)
- **Psychosis - Neurodevelopmental Disorder with Neuroprogression, Critical Period for Early Intervention, Relapse Prevention and Neuroprotection of Antipsychotic Treatment.**
  Dr LEE Wing-kong
  (Clinical Associate Professor (Honorary), Department of Psychiatry, The Chinese University of Hong Kong)

Session Vb – Oncology
Chairpersons: Dr MAN Chi-wai & Dr NG Chun-kong

- **Personalized Management of Lung Cancer**
  Dr David CL LAM
  (Clinical Assistant Professor, Department of Medicine, University of Hong Kong)
- **Colorectal Cancer Screening**
  Dr William CS MENG
  (Specialist in General Surgery)

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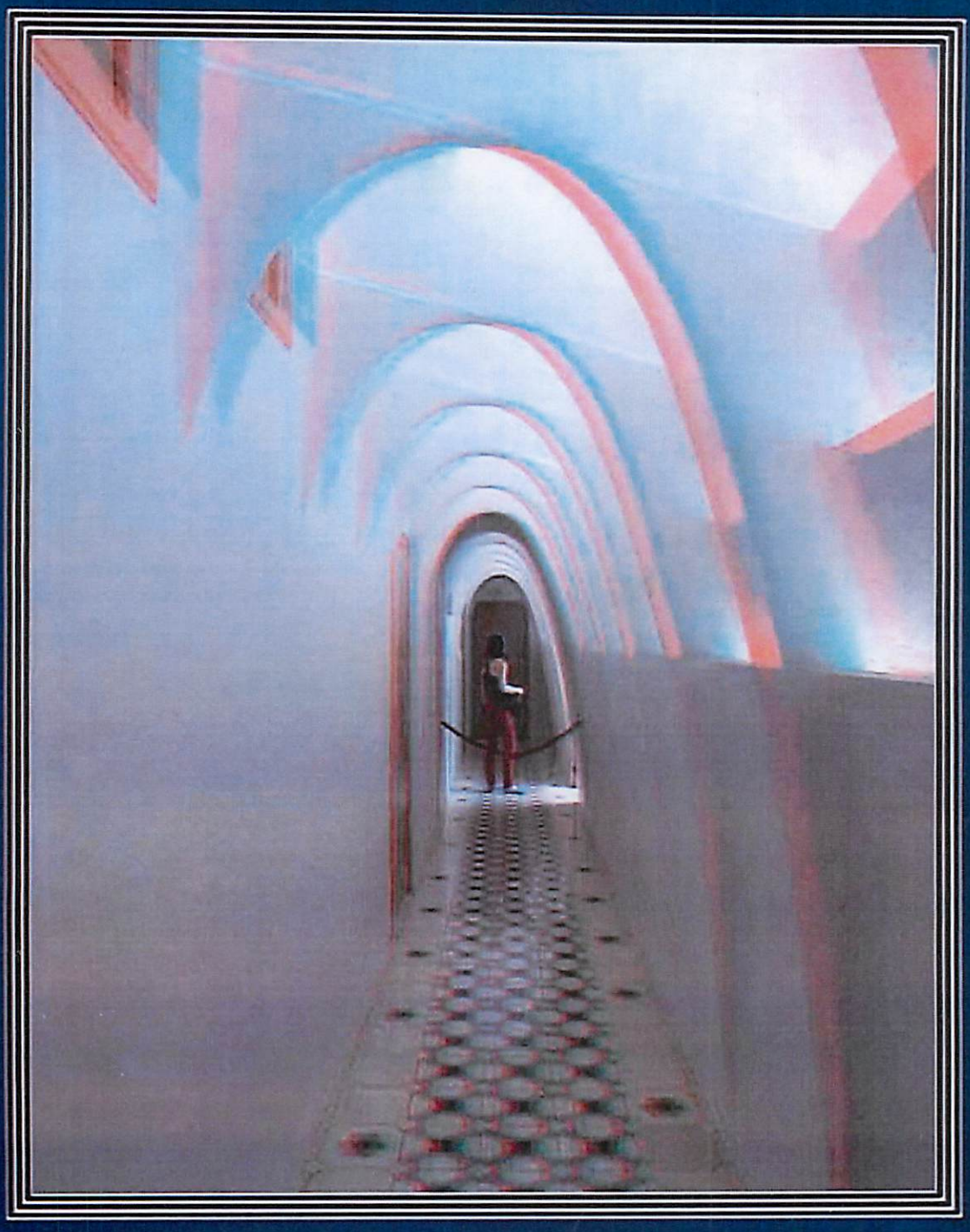
Dentistry



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